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Color Coherence in Multijet Events at CDF

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COLOR COHERENCE IN MULTIJET EVENTS AT CDF

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ABSTRACT

Results of a search for an evidence of color coherence in CDF $\bar{p}p \rightarrow 3jet + X$ data from the 1988-89 run high statistics inclusive jet sample ($4.2pb^{-1}$ of integrated luminosity) are presented. We study the geometric correlation between the third jet (regarded as the product of "soft" branchings in the Leading Log Approximation) and the second one, in comparison to Isajet and Herwig shower Monte Carlos predictions. A geometric variable for this correlation is found which is sensitive to interference: the qualitative agreement of Herwig (with coherent shower development) to the data distribution, contrasted to the disagreement of Isajet (independent development) is consistent with the observation of a color interference effect. Further evidence for this interpretation comes from "switching off" interference in Herwig by means of a proper event selection, which yields a distribution much similar to the Isajet one.

1. Introduction

The detection of color coherence effects in the $\bar{p}p$ environment, as compared to e^+e^- collisions[1], is complicated by the presence of underlying event radiation and by color flowing from initial to final state.

To overcome the problem of the large background radiation we tried to detect the effect in events where the coherent radiation clusters in a secondary jet. We consider the interference accounted for in the Leading Log Approximation by constraining the phase space for the gluon radiation[2,3]. Choose the particular case where *bremsstrahlung* gluons are emitted either from initial or final state partons of a hard $2 \rightarrow 2$ process: then this kind of interference can only occur if initial and final state are *color connected*, i.e. a color line can be traced from the initial to final state[2] (Fig. 1a). Fig. 1b illustrates how, as a result, radiation tends to occur within cones centered on the emitting parton and limited by the color connected parton directions, outside which interference is fully destructive (in this approximation). The overlap of the emission cones will give rise to a pattern of enhanced and depleted radiation (Fig. 1c). In the hypotesis that radiation materializes in a third (softer) jet, we search for an enhancement of third jet probability in the region between the second jet and the beam.

2. Analysis

2.1. Event selection

The jet identification is performed through a fixed cone algorithm with cone

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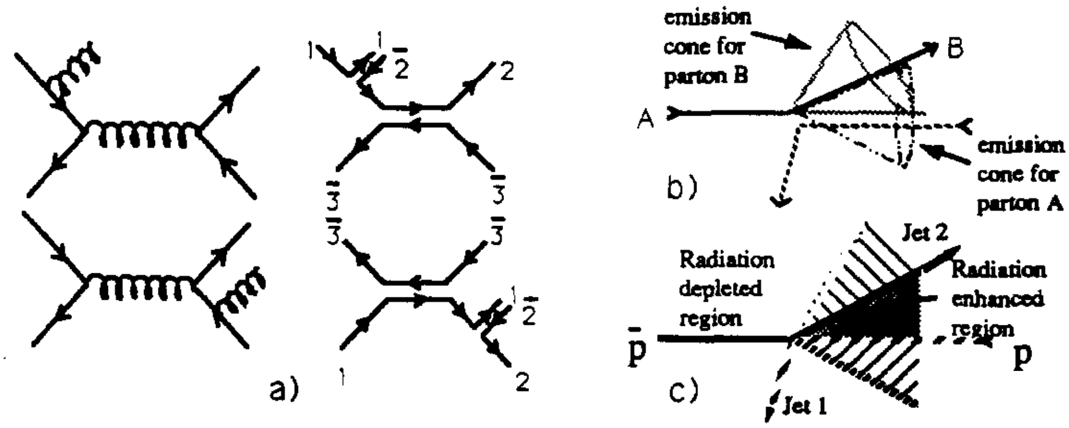

Figure 1: a) Soft gluon emission diagrams and a corresponding color configuration yielding color interference. b) Radiation emission cones for initial state parton A and final state parton B. c) Overlapping of cones produces a region of enhanced radiation.

radius $R = \sqrt{\eta^2 + \phi^2} = 0.7$; jets are ordered in E_T, and the first jet is required to have $E_T > 110$ GeV for full trigger efficiency. The two leading jets are required to be central ($|\eta| < 0.7$) and opposite in ϕ to within 20 degrees to suppress hard branchings. The third jet is required to have $E_T > 10$ GeV for full clustering efficiency.

Geometric correlation between 2nd and 3rd jet is studied using the pseudo-rapidity distance $H = sign(\eta_2)(\eta_3 - \eta_2)$ (notice the $sign(\eta_2)$ is introduced so that $H > 0$ in the enhanced region) and the azimuth separation $\Phi = \phi_3 - \phi_2$. As we shall see the signal for interference is better displayed using the polar variables $R = (H^2 + \Phi^2)^{1/2}$ and $\alpha = arctan(H/|\Phi|)$. We require $1.1 < R < \pi$ for uniform α acceptance.

2.2. The α distribution

The α distribution is obtained for events with the above cuts. From the above considerations we expect regions $\alpha \simeq \pm\pi/2$, corresponding to the half plane containing the second jet and beam to be enhanced with respect to $\alpha \simeq 0$. Fig. 2a shows the α distribution for data (dots) in comparison to Monte Carlo predictions. Absence of interference would yield a negative slope, as illustrated by the Isajet[4] distribution (dashed), which does not include interference effects. The Herwig[5] Monte Carlo, on the other side, implementing L.L.A. interference, yields a distribution (solid) with positive slope towards $\alpha = \pi/2$, in qualitative agreement with CDF data. Notice that the change in slope takes place towards α values corresponding to the region of enhanced radiation in fig. 1c. To check that the difference between Herwig and Isajet is primarily due to interference, events producing interference in the Herwig sample are removed by selecting *color unconnected* processes. The Herwig "incoherent" sample thus obtained yields a distribution (dotted curve in fig. 2a) much similar to Isajet.

The noticeable difference between the coherent and incoherent sample distributions in Herwig and the fact that *color unconnected* processes can only have two quarks in the final state of the hard process suggests a possible use of α cuts

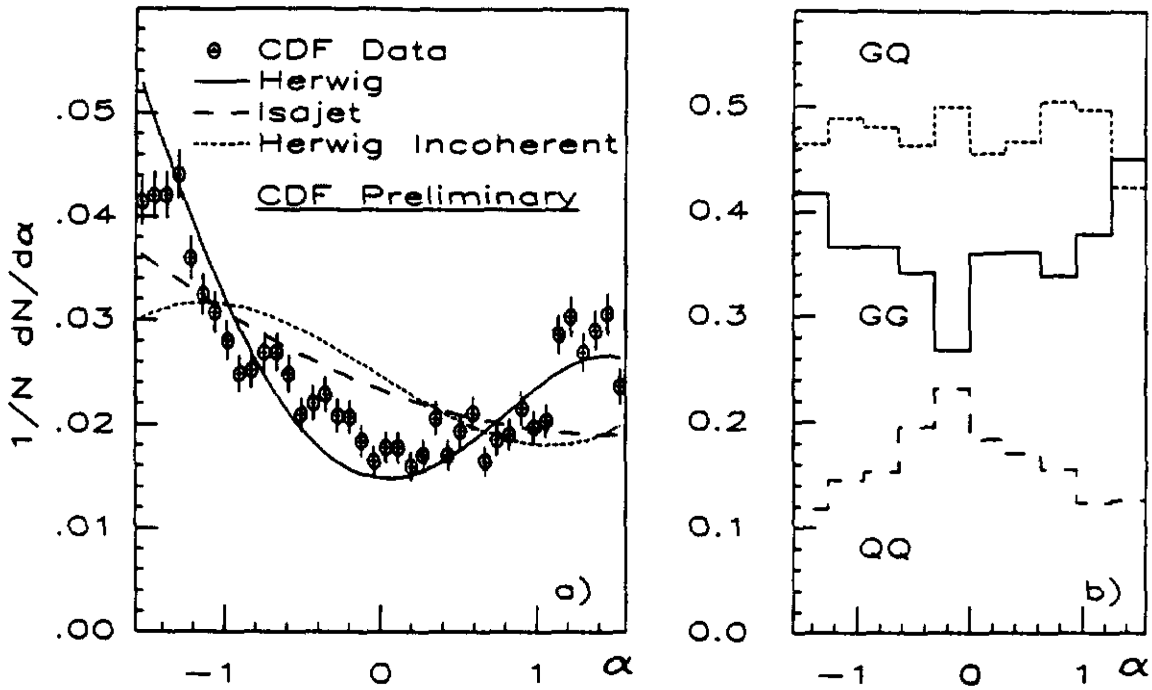

Figure 2: a) α distribution for CDF data; superimposed are the fits to Isajet (dashed) and Herwig (solid) distributions. Errors are statistical. The change in slope towards $\alpha = \pi/2$ is consistent with being an effect of color interference. The "incoherent" Herwig distribution (dotted) is obtained by selecting *color unconnected* processes in the Herwig sample. b) Fractions of events with one quark and one gluon, two gluons, and two quarks in the final state as a function of α (Herwig).

to enrich quark-jet samples. Fig. 2b shows the fraction of events with one quark and one gluon (dotted), two gluons (solid) and two quarks (dashed), respectively, in the final state, as a function of α (Herwig). The two-quark final state has about a factor 2 enhancement in the region $\alpha \simeq 0$.

3. Conclusions

The study of soft third jet correlation in comparison to Monte Carlos puts into evidence an effect compatible with QCD interference. This is the first observation of a color coherence effect at $\bar{p}p$ colliders.

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